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Strut Shaping of 34m Beam Waveguide Antenna for Reductions in Near-Field RF and Noise Temperature

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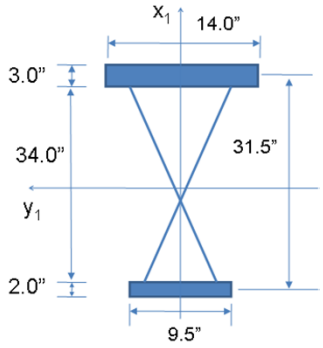
Background

Goldstone 70m Antenna

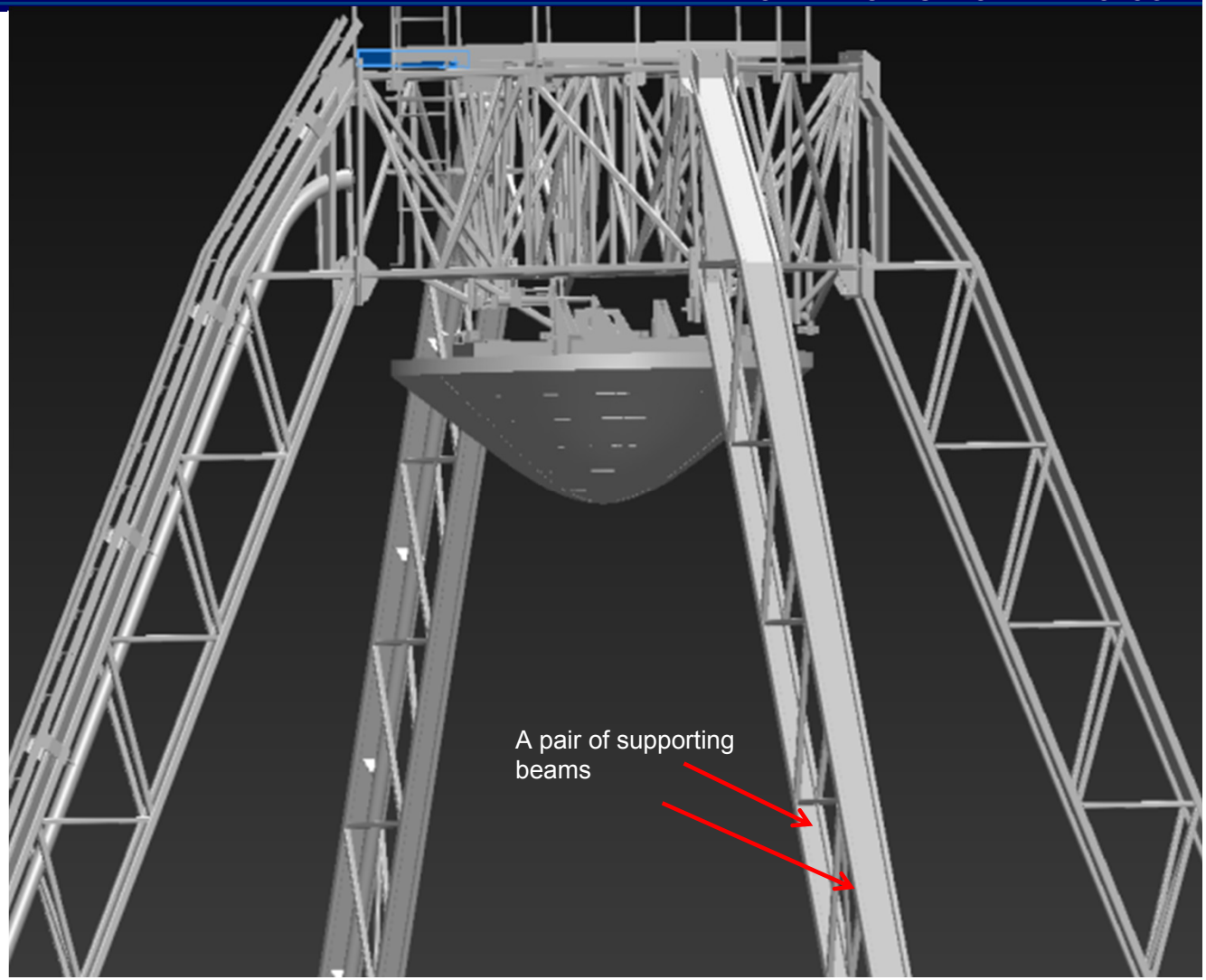
34m BWG Antenna Cluster

- **The DSN provides uplink (7.165 GHz) and downlink (8.4 GHz) communication capability for NASA's deep space missions: Mars Exploration Rovers, Mars Orbiters, Cassini, Kepler, Voyager, etc.**
- **The DSN employs one 70m and a number of 34m beam waveguide antennas at each of 3 complexes: Goldstone, Madrid, and Canberra**
- **Current maximum EIRP available is a 20 kW X-band uplink on the 70m antennas**
- **DSN is in the process of backing up the 70m uplink capability by increasing the uplink power on 34m antenna from 20 kW to 100kW (In the event of spacecraft emergencies, 70m faults)**
- **This has led to investigate ways to reduce the RF exposure in RF near-field of the DSN's 34-m antennas.**

34-m Antenna Subreflector and Supporting Strut Configurations

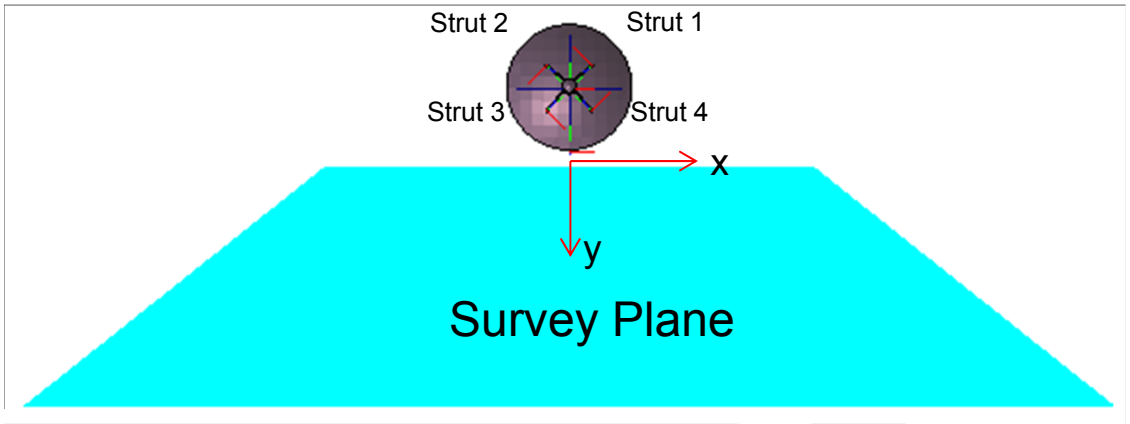


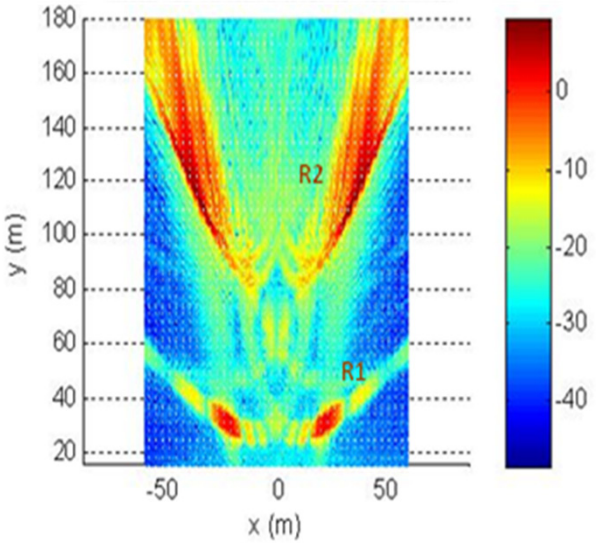
After: V. Jamnejad and N. Llombart Juan, “An Analysis of Near Fields of 34m Antennas of JPL/NASA Deep Space Network”, 2011 IEEE International Symposium on Antennas and Propagation (APSURSI), pp. 3011 – 3014.

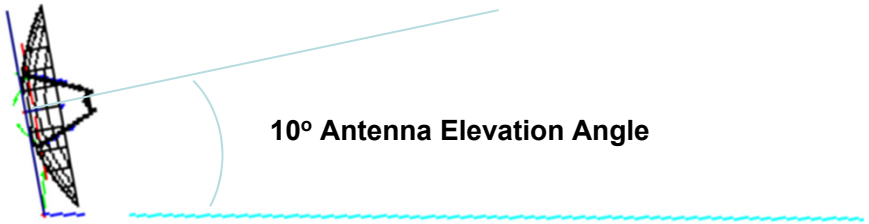


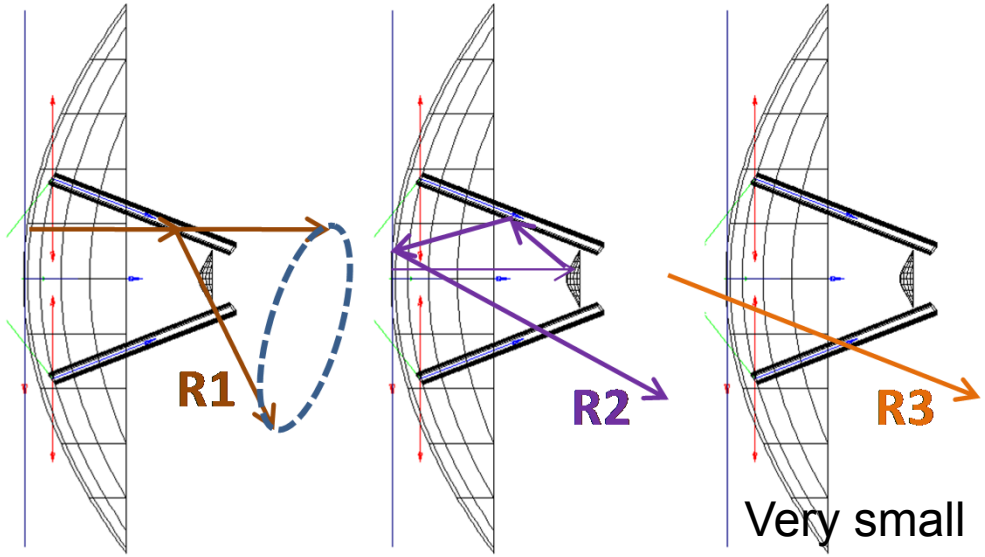
Major Antenna Scattering Contributions

Calculation includes contribution from all struts but the major contribution is due to scattering from Struts 1 and 2 as shown.



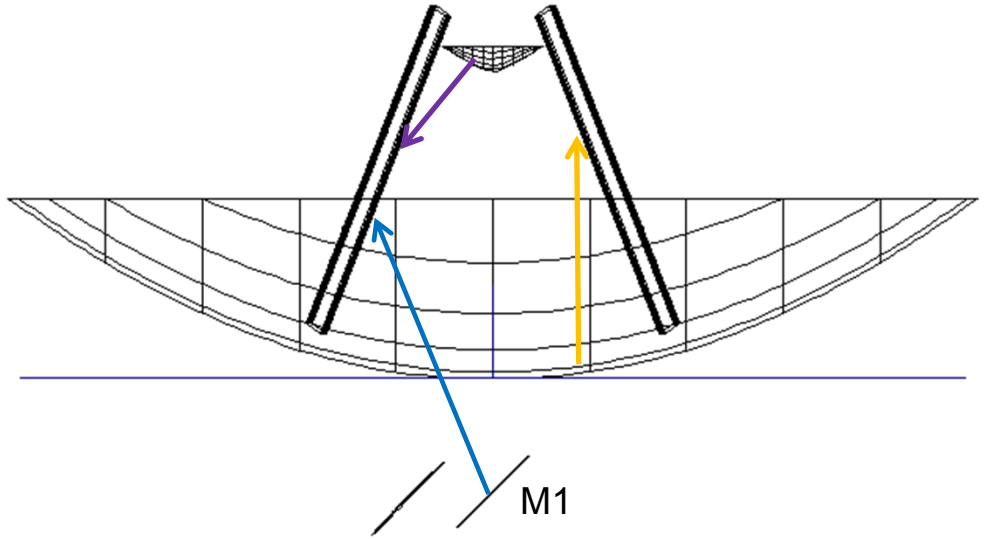




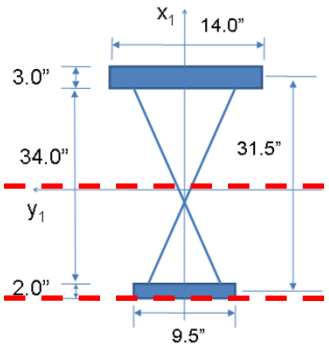


Relative Power Incident on the Struts from Main, Sub and the Virtual Feed (M1)

Approximate Relative power hitting a single Strut From:	1 Strut	4 Struts
From Subreflector	8.3E-03	0.0332
Plane Wave Coming from Main Reflector	2.53E-03	0.010104
From M1 Mirror (Virtual Feed at F1)	2.11e-6	0.00000844

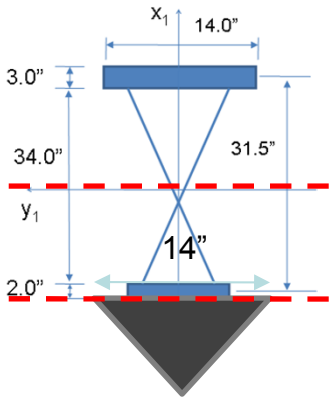


Strut Modification Modeling/Evolution

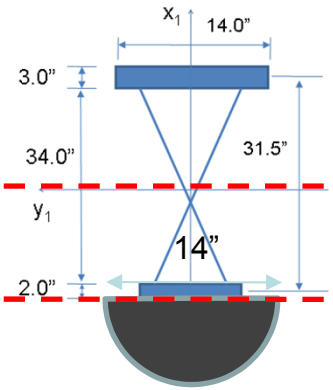


After: V. Jamnejad and N. Llombart Juan

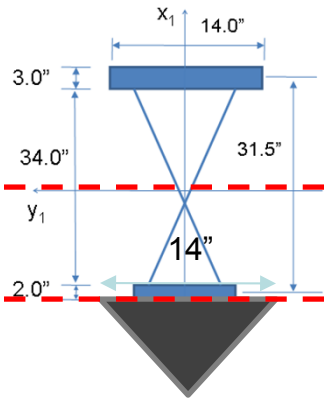
Infinity thin sheet located half way between the two beams giving rise to the same scattered field as calculated and measured



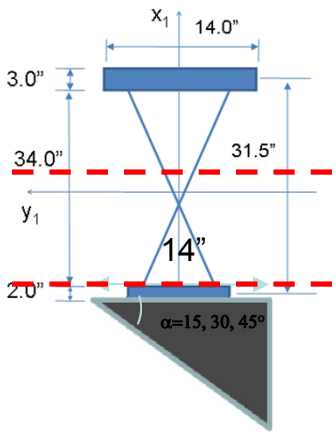
90° Wedge Shaped Placing Struts’ Beam in its Shadow region



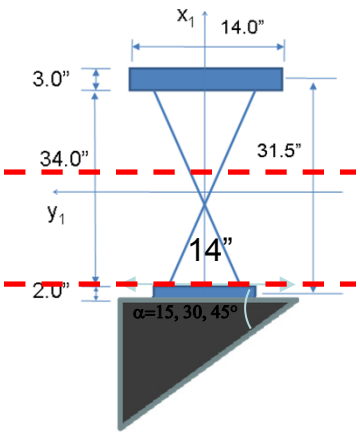
Half Cylinder Shaped Placing Struts’ Beam in its Shadow region



90° Wedge Shaped (α=45°)Placing Struts’ Beam in its Shadow region

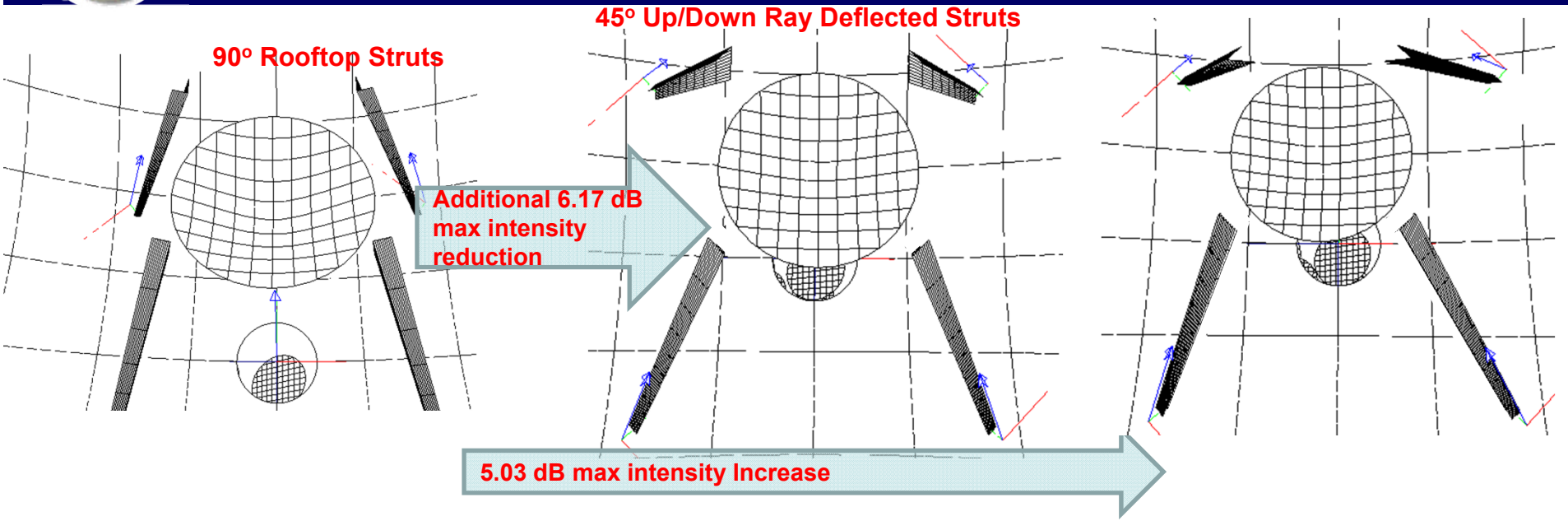


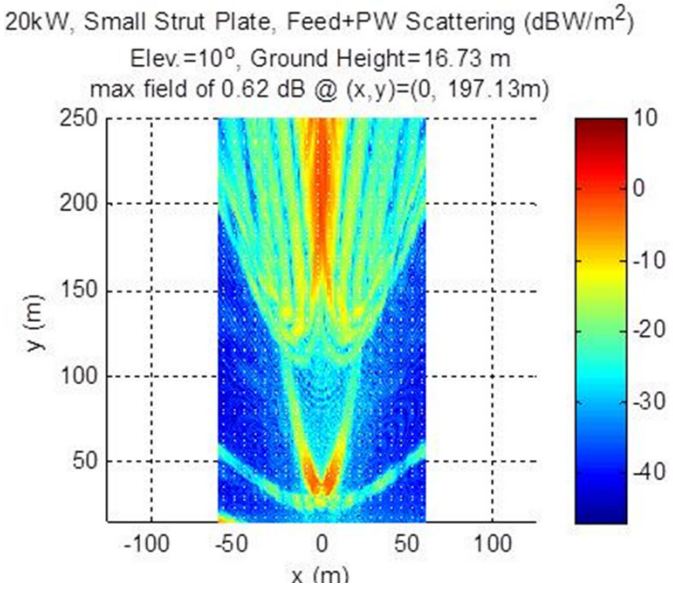
α=15, 30, 45° Wedge Shaped Placing Struts’ Beam in its Shadow region

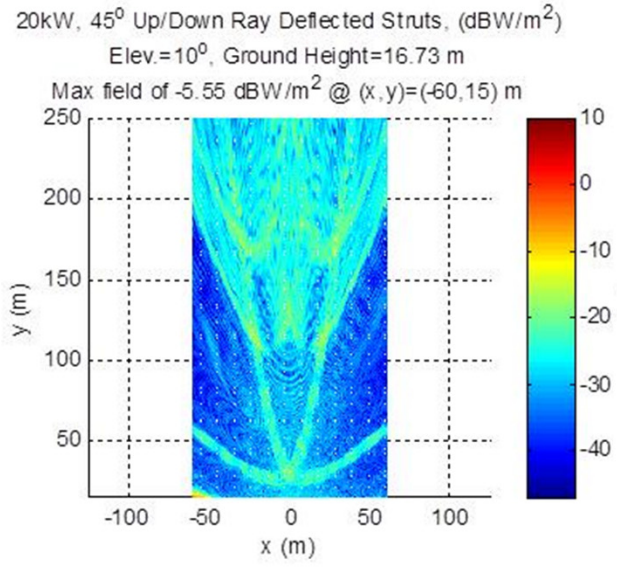


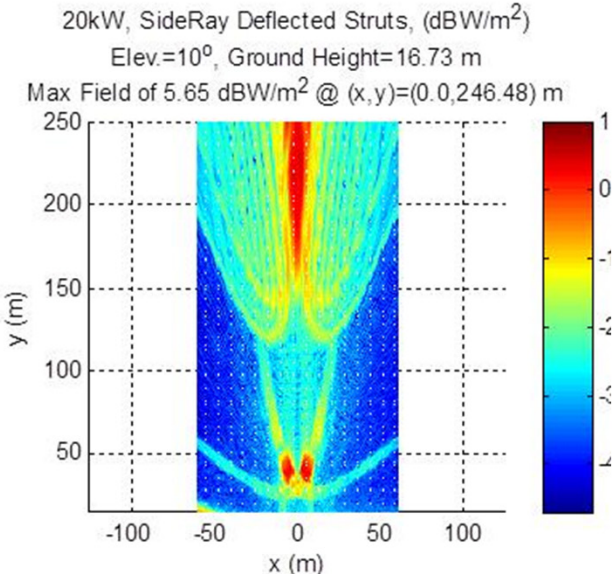
α=15, 30, 45° Wedge Shaped Placing Struts’ Beam in its Shadow region

Shaping Using 90° Rooftop vs. Up/Down Ray and Side Ray Deflected Plates (Angled @ 45°)

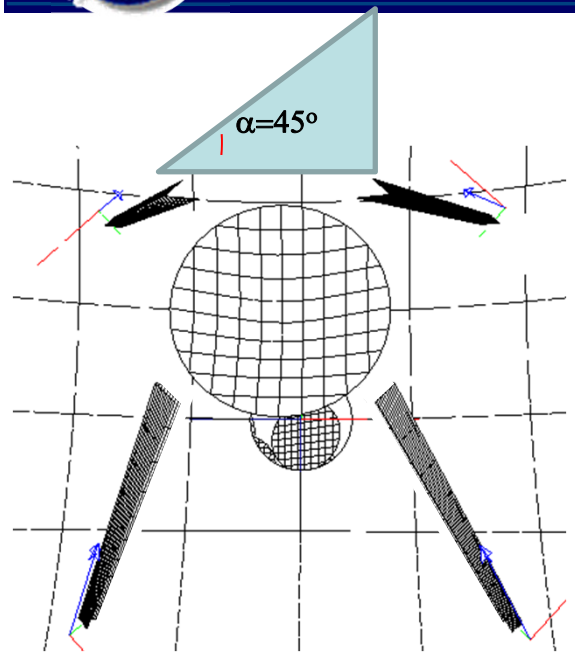


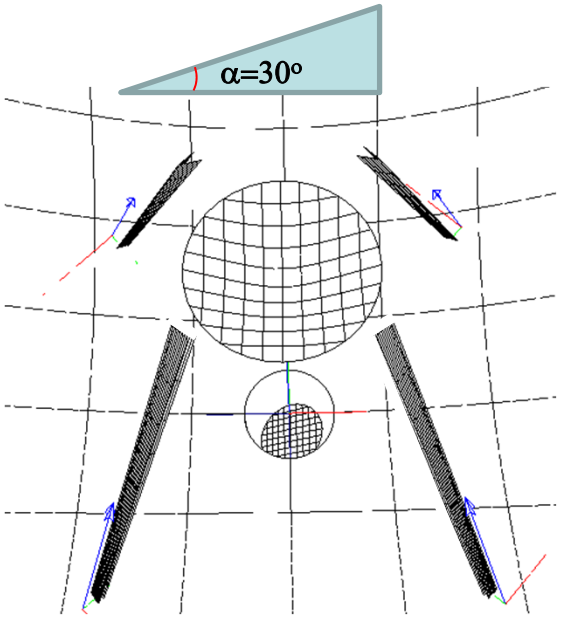


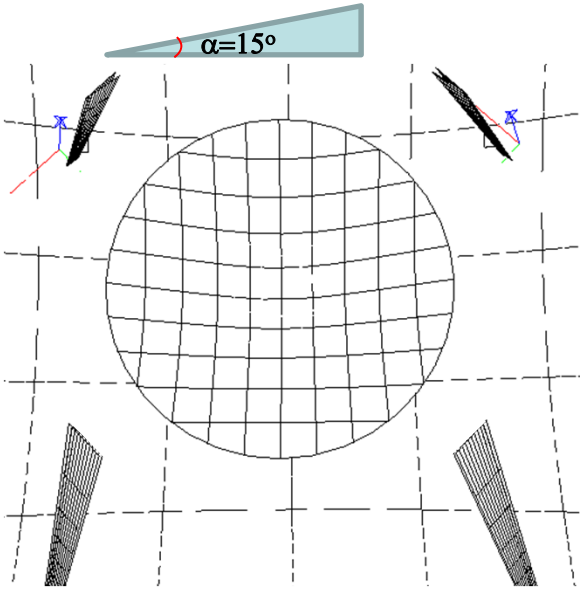


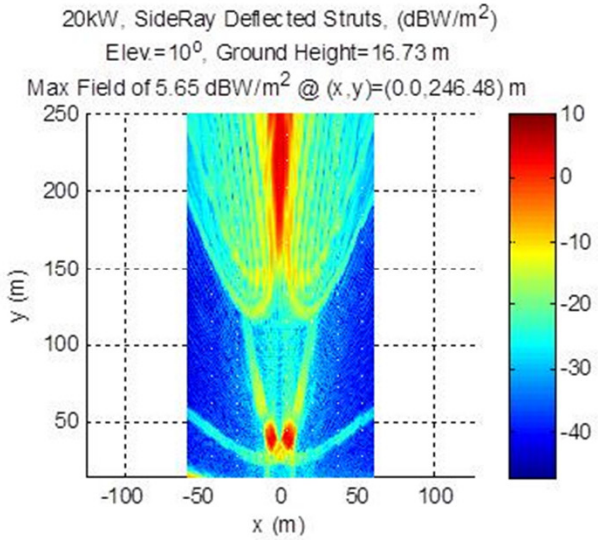


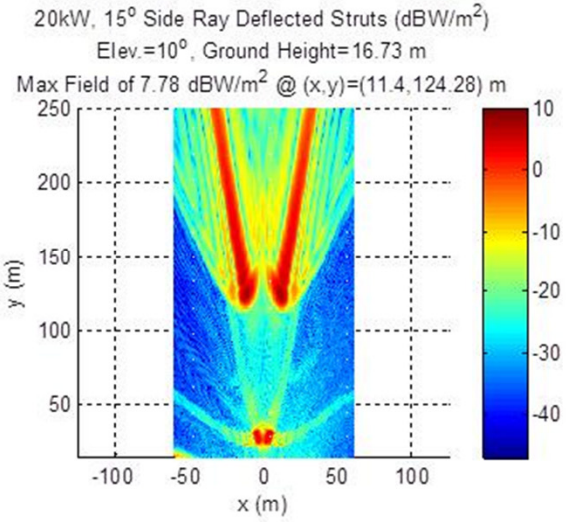
Ground Illumination for Incorrect RF Shield Orientation
as a Function Wedge Angle α

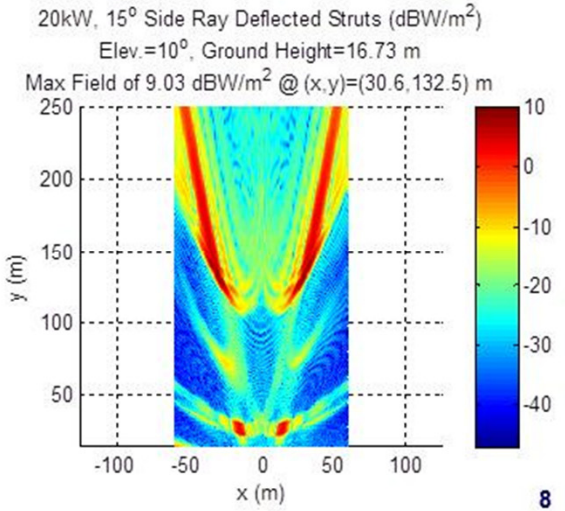




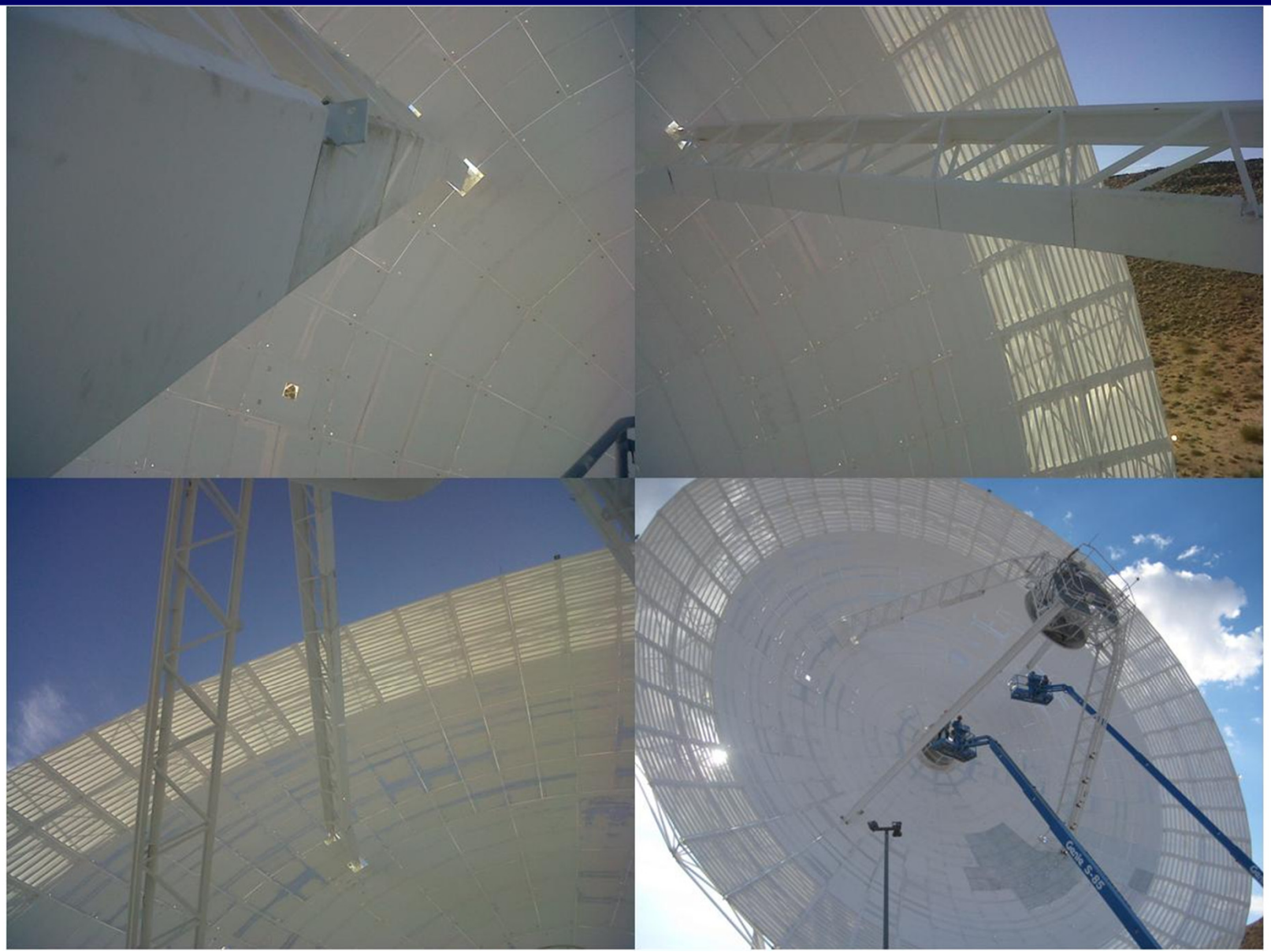








Mounting the RF Shields

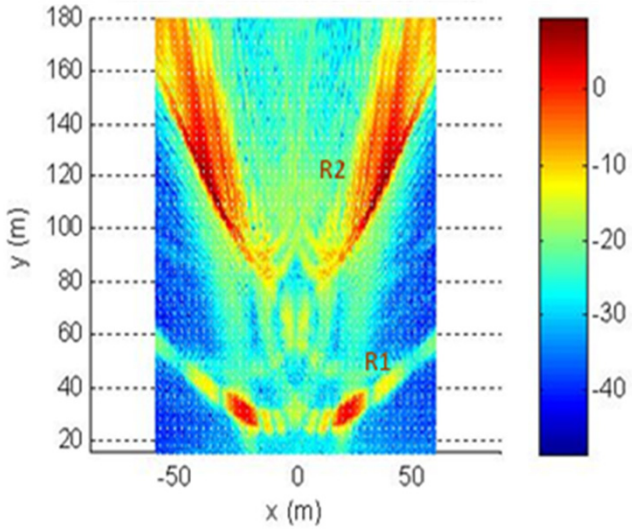


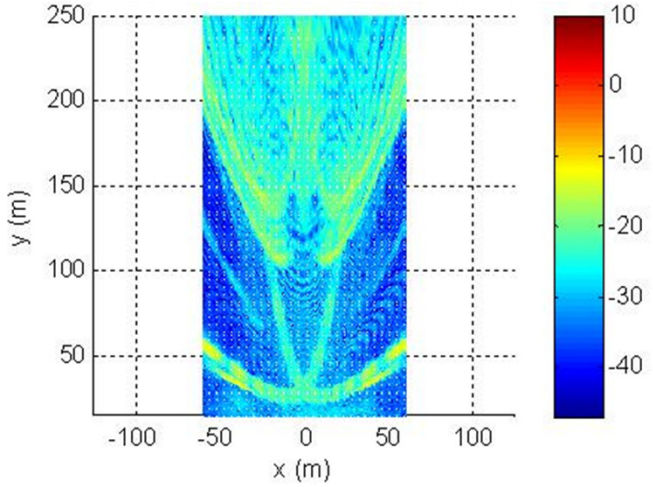
RF Survey Area

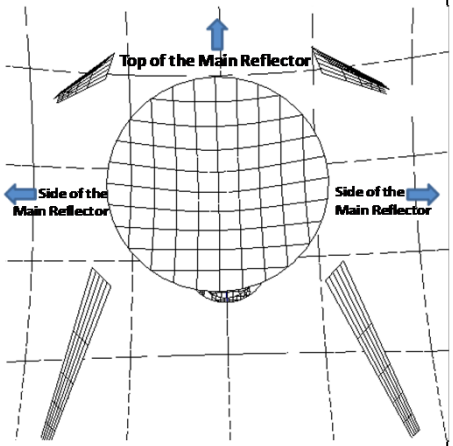
Narda Field Strength Meter NBM-550

Predicted vs. Measured Ground Illumination Before and After Installing the RF Sheilds

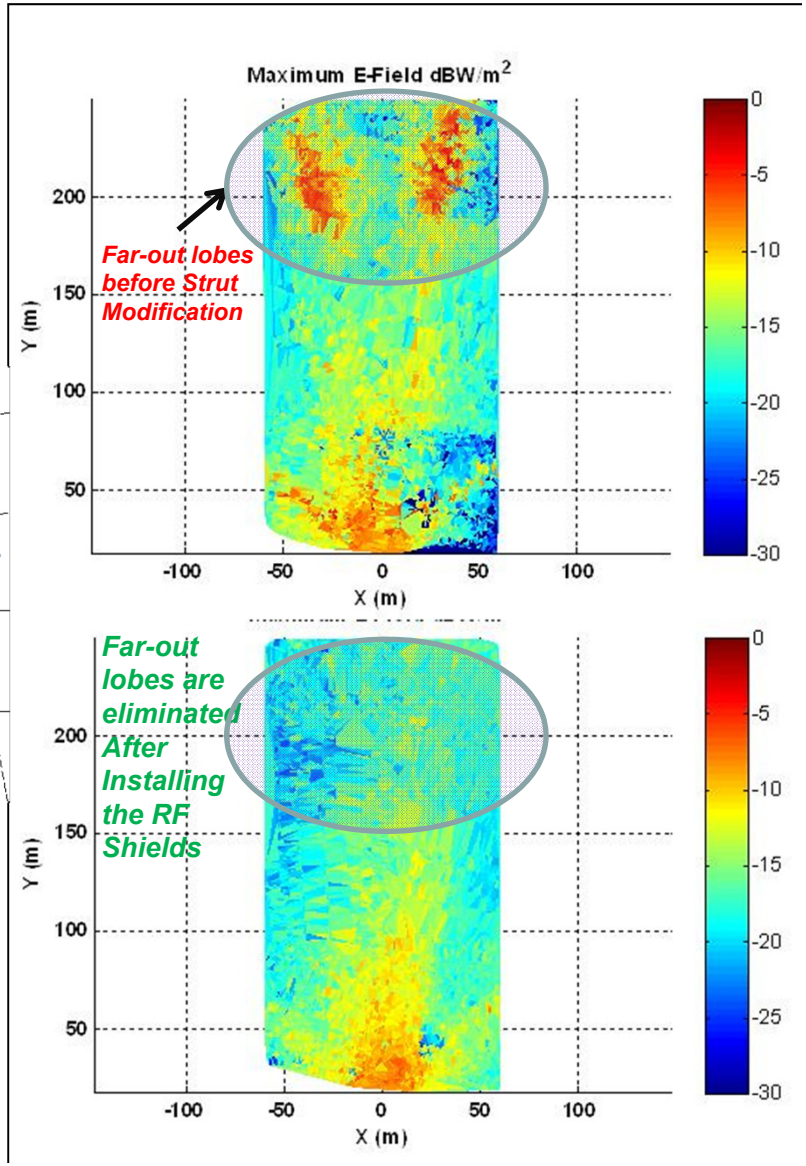
Calculated





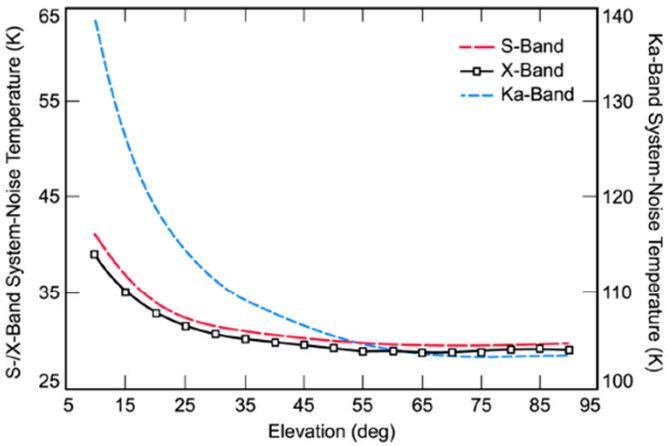


Measured

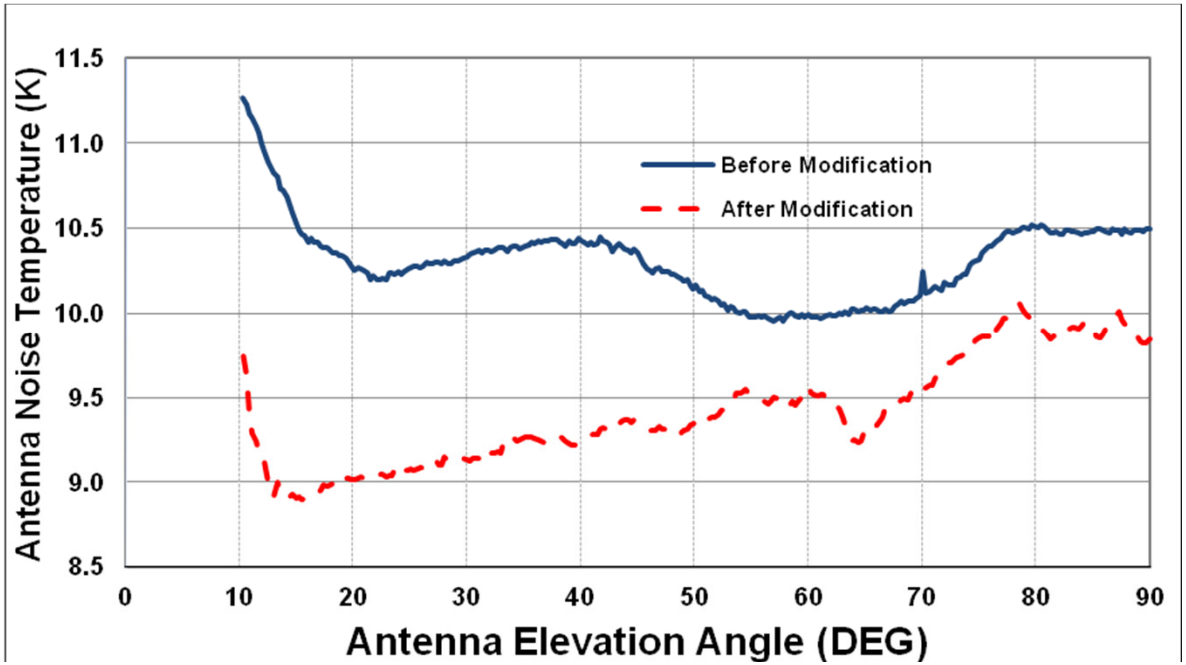


Improvement in Antenna Noise Temperature

- Antenna noise temperature contributes to more than 1/3 of the overall system noise temperature
- Antenna noise temperature is reduced over the entire elevation angle by as much as 0.5 K.
- Noise Temperature close to the low elevation angles (10º-15º) (where the strut modification is designed for) has reduced the noise temperature by as much as 1.5 K further insuring that the RF energy scattered by the struts is more likely re-directed toward the sky.



Overall System Noise Temperature from: Large Antennas of the Deep Space Network, William Imbriale (Deep-Space Communications and Navigation Series)

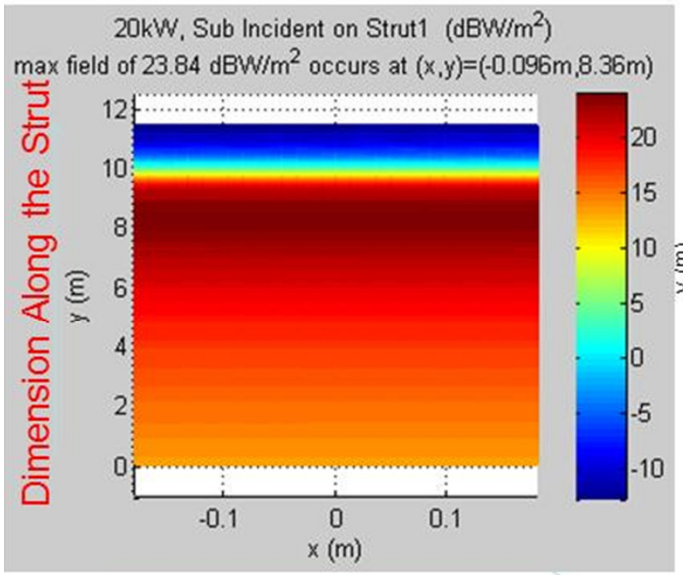


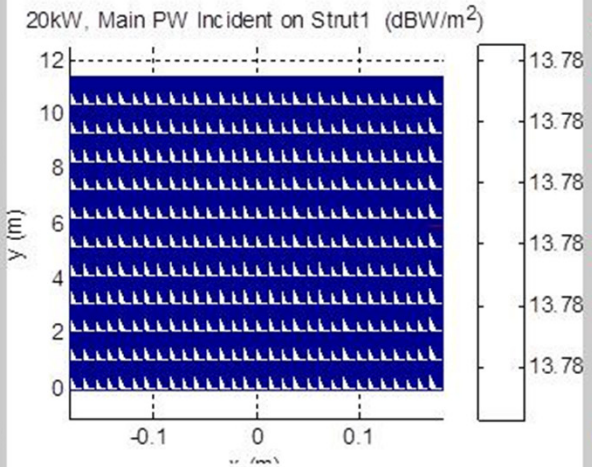
Summary & Conclusions

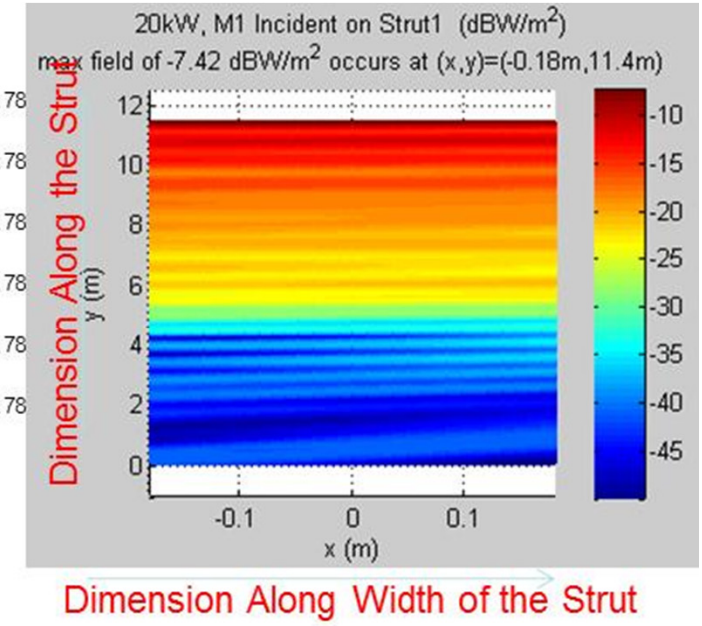
- The strut structure of NASA's DSN 34 m BWG antenna was modified by introducing an RF shield that reduces near-field RF exposure while simultaneously improving the antenna noise temperature.
- The RF shield is a low-cost, low mass solution which maintains the structural integrity of the existing mechanical support
- The RF ground exposure is reduced by nearly 15 dB in the far-out lobes.
- Furthermore, the RF shields have reduced the antenna noise temperature between 0.5 K to 1.5 K over the entire range of antenna elevation angles.

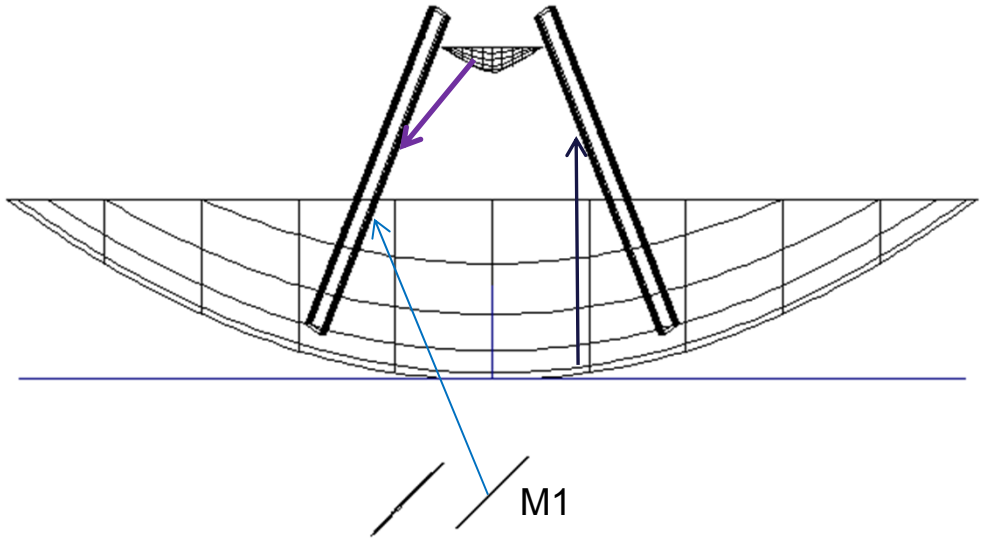
Backup Slides

Incident Field Distribution on Strut 1 From Sub, Main Plane Wave and M1
Strut is assumed to be a flat Plate.







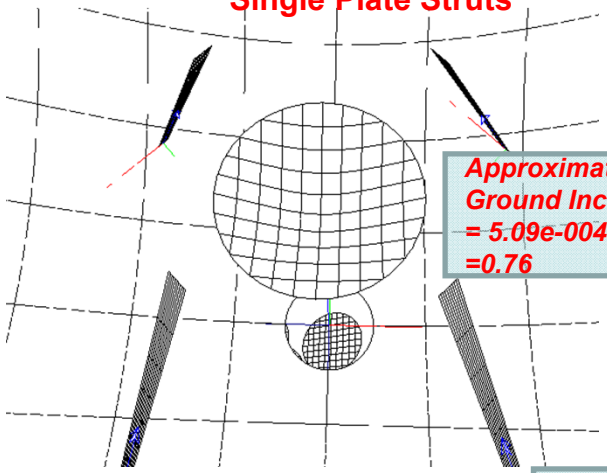


Calculations of Δ Ground Illumination

Single Plate Strut vs. Shaping Using 90° Rooftop & 30° Tilted Plate (500m range)

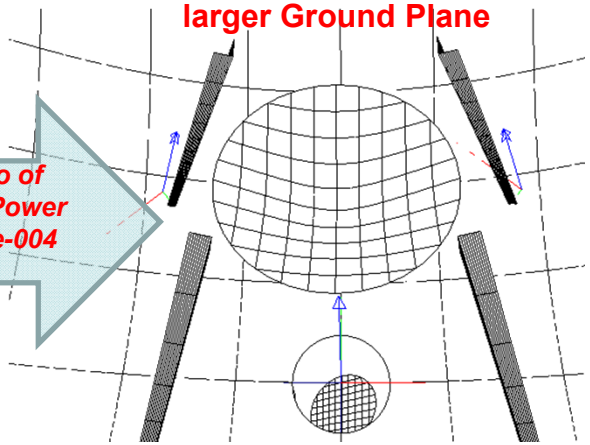
- The following calculation is based on fraction of incident power for ground field intensity up to 500m for the rooftop and 30° Tilted Plate Struts.
- Note ground calculations over far-out angles is not accurate due to reflector blockage.
- Calculation is based on ground map at 7.165 GHz (TX Freq). Actual computation must be made at RX freq of 8.4 GHz.

Single Plate Struts

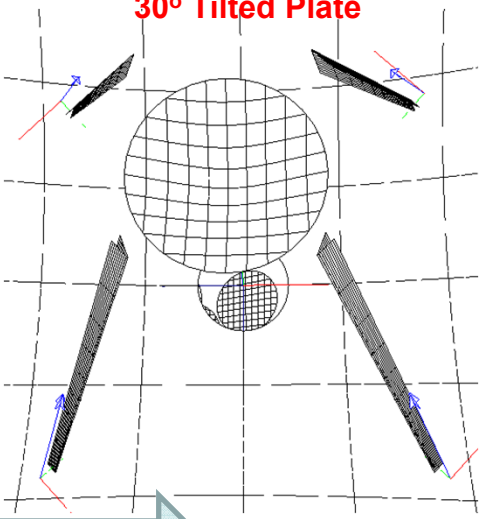


Approximate Ratio of Ground Incident Power = 5.09e-004 / 6.74e-004 =0.76

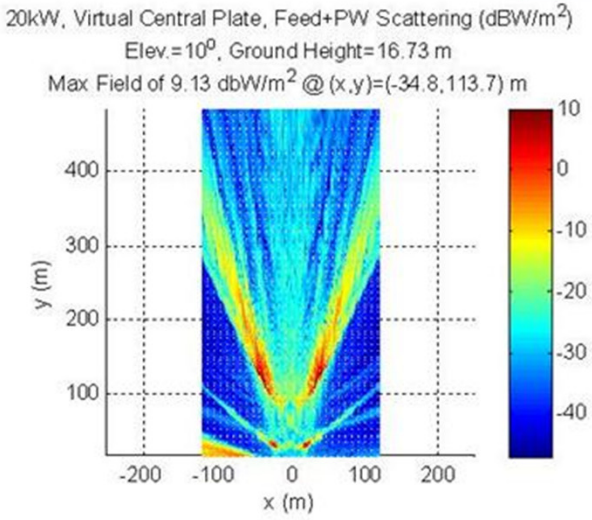
90° Rooftop Struts Over a larger Ground Plane

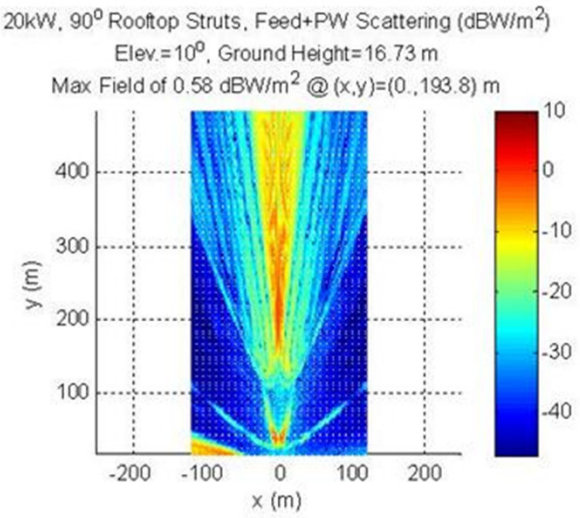


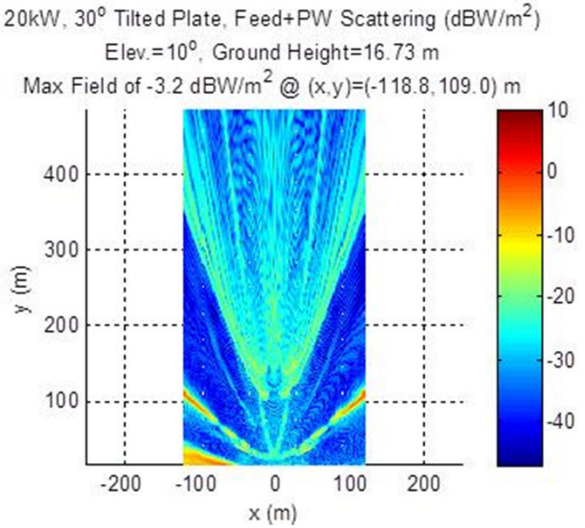
30° Tilted Plate



Approximate Ratio of Ground Incident Power 1.13e-4 / 6.74e-4 = 0.17







Summary of Strut Modified Configurations and Their Respective Performances

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Summary of Strut Modified Configurations and Their Respective Performances					
Cases	Max Field Intensity (dBW/m2)	Max Field Location (x,y) meters	Max Intensity Reduction WRT the Existing Single Plate Strut	Ratio of Ground Incident Power WRT the Existing Single Plate Strut: Gound Plane 250mx500m	Comment
Single Plate Strut (Centrally Located)	9.7	(-36,115)	0.00	1.00	Approximation to dually located strut beams
90 DEG Rooftop	0.62	(0,197)	-9.08	0.76	
Half Cylinder	-0.71	(24,138)	-10.41		Radius =7"
Wedge Shaped (Up/Down Ray Deflected)					
Wedge Angle alpha=15 Deg	2.85	(31,37)	-6.85		
Wedge Angle alpha=30 Deg	-5.8	(-60,15)	-15.50	0.17	Best case
Wedge Angle alpha=45 Deg	-5.55	(60,-15)	-15.25		
Wedge Shaped (SideRay Deflected)					
Wedge Angle alpha=15 Deg	9.03	(31,133)	-0.67		Wedge angle is approaching to the Centrally Plate Strut
Wedge Angle alpha=30 Deg	7.78	(11,124)	-1.92		
Wedge Angle alpha=45 Deg	5.64	(0,246)	-4.06		Causes field enhancement along the antenna axis

Comment: Shaped struts are dimensioned in a way to completely place the larger of the two beams (14" wide) in their shadow region